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WIDEBAND SUBARRAY SYSTEMS: EVOLUTION OF A RESEARCH AREA

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INTRODUCTION

R.W.P. King has always insisted that his students look beyond the trivial to uncover the subtleties that, (more often than not) require detailed electromagnetic analysis and reveal fundamental properties. The purpose of this paper is to look at an important topic in scanning arrays to show how the interaction of obvious geometrical features and very subtle electromagnetic features are shaping this evolving technology.

This paper discusses developments in the technology of transform-fed wideband scanning arrays. These antennas were introduced over 40 years ago, and proposed for a large number of scanning applications, but because of poor efficiency and high cost, have not found application in fielded systems. Recent technological innovations including MEMS phase shifters and digital beamforming have re-focused attention on these systems, which for many applications remain the most viable array architecture for large wide band arrays.

WIDEBAND SUBARRAY SYSTEM

Figure 1 shows the classic configuration of this wideband system, as consisting of a large equal path length objective lens fed by an MXM Fourier Transform (multiple beam) feed, either a Butler Matrix or a lens with (approximately) orthogonal multiple beams (Rotman Lens). The purpose of the complex feed is to form subarrays that overlap across the objective lens, and that radiate pulse-shaped subarray patterns. The subarray input ports are shown at surface "D" in the figure, and these ports are time delayed as appropriate for transmit and receive. The transmission lines between surfaces "A" and "B" contain "N" phase shifters to steer the pulse-shaped subarray pattern to the desired angle at center frequency. The array of subarrays forms a time-delayed beam that points in the desired direction at all frequencies, but the subarray patterns are phase-steered, and so they narrow and move toward broadside at the higher frequencies. They broaden and move toward end-fire at the lower frequencies. This sliding "window" determines the system bandwidth limits.

Although Figure 1 shows a lens as the objective, reflectors with transform feeds have also been studied, as have confocal reflector systems using simple array feeds. Each of these variations has quite different scanning properties. Another important configuration has the surface-B as a planar surface, with all spherical correction carried out with phase shift or time delay in the lens.

Simple geometric relations and array theory can describe subarray size, bandwidth and pattern characteristics for this idealized system. It is, however, the combination of electromagnetic features and cost that are determining the future directions of this technology.

The published work of Southall and McGrath [1] discussed many effects caused by mutual coupling between probes at the various interfaces. These included narrowed element patterns on surface–B due to wide element spacings, and (among other design issues) element pattern narrowing within the Rotman multiple beam lens feed. This necessitated the insertion of additional loaded pickup probes in the Rotman Lens, and added 3dB loss.

Practical considerations conspire with these electromagnetic limitations to further restrict design choices. Because of the feed losses, some consideration has been given to adding full T/R modules at every element between surfaces A and B. Unfortunately the cost of T/R modules has not decreased according to optimistic projections, and since these systems may contain tens to hundreds of thousands of elements at the radiating surface "A," this option is not yet viable.

Similarly, the use of (much higher power) T/R devices at the input to the transform network (surface-D) is subject to between 4 and 6 dB loss, and this to appears an unrealistic choice. One remaining practical choice is to use high power T/R devices at surface-C, the feed array radiating surface. Unfortunately, there is a severe dynamic range requirement at this surface, with some scan angles requiring nearly all the power at a single port.

There may be several solutions to this problem, certainly there is a solution for an array with time delay in a single plane [2]. In addition, we have some preliminary results that describe a scheme wherein the feed system departs from an orthogonal Fourier Transform network, and in fact can only be a digital beamformer.

CONCLUSION

In keeping with this celebration of Ronald King's continued enthusiasm for the subtleties, the goal of this paper has been to describe a fertile area of antenna research, and to show some of its evolution. This evolution from a purely geometric idea to a realistic and affordable piece of antenna technology has been continually slowed by subtle and not-so-subtle electromagnetic effects. The paper

describes these effects and a variety of proposed solutions in addition to giving an outline of future work.

REFERENCES

[1] H.L. Southall and D.T. McGrath, "An Experimental Completely Overlapped Subarray Antenna," *IEEE Transactions on Antennas and Propagation Magazine,* Vol AP-34, No. 4, pp 465-474, 4 April 1986

[2] R. J. Mailloux, "Constrained Feed Technique for Subarrays of Large Phased Arrays," IEEE Electronic Letters, Vol 34, No. 23, pp 2191-2193, 12 November 1998

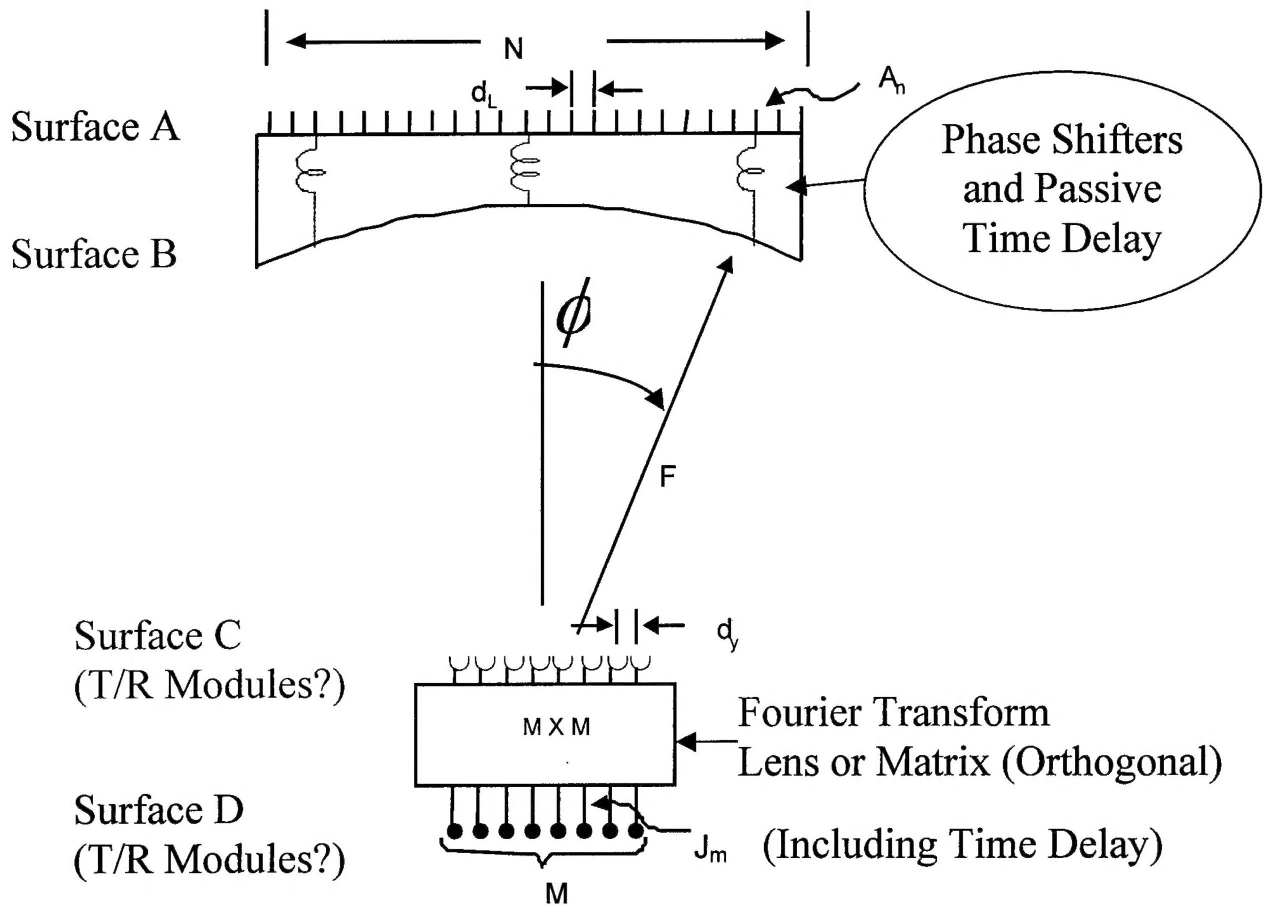

Figure 1: Basic Wideband Subarray System